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Non-minimal two-loop inflation

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ABSTRACT

We investigate the chaotic inflationary model using the two-loop effective potential of a self-interacting scalar field theory in curved spacetime. We use the potential which contains a non-minimal scalar curvature coupling and a quartic scalar self-interaction and which was found in Ref. [1]. We analyze the Lyapunov stability of de Sitter solution and show the stability bound. Calculating the inflationary parameters, we systematically explore the spectral index n_s and the tensor-to-scalar ratio r, with varying the four parameters, the scalar-curvature coupling ξ_0, the scalar quartic coupling λ_0, the renormalization scale μ and the e-folding number N. It is found that the two-loop correction on n_s is much larger than the leading-log correction, which has previously been studied in Ref. [2]. We show that the model is consistent with the observation by Planck with WMAP [3,4] and a recent joint analysis of BICEP2 [5].

1. Introduction

The measurements of the cosmic microwave background (CMB) fluctuations become increasingly important from the perspective of not only cosmology but also elementary particle physics. Useful indicators of the CMB fluctuations are given by the scalar (or density) fluctuations, δ, the spectral index, n_s, and the tensor-to-scalar ratio, r. In the inflation scenario a non-vanishing potential energy density of a scalar field induces exponential expansion on the universe. The origin of the CMB fluctuations is found in the quantum fluctuations of the scalar field. It is expected that these inflationary parameters restrict the models of particle physics. Although we have observed only one elementary scalar field, i.e. Higgs, it is quite natural to assume that other scalar fields exist and play a decisive role for the energy density and its fluctuation at early universe.

In this paper we consider that the inflaton field is a real scalar field with a quartic self-interaction and a non-minimal scalar-curvature interaction at high-energy scale and study a possible model consistent with the CMB fluctuations at the two loop level. Inflation is thought to occur near the Planck scale. In such high energy scale the quantum correction may have some remarkable effect on the inflationary parameters. It is known that the spectral index and the tensor-to-scalar ratio are independent of the scalar quartic coupling, λ_0, at the tree level. It is also known that there is an attractor on the (n_s, r) plane. The inflationary parameters, n_s and r, converge to their universal model-independent values at the large scalar-curvature coupling limit [6,7]. Note that RG behavior of scalar curvature coupling ξ is defined by the behavior of the corresponding quantum field theory at high energy (see: [8,9]) so that it maybe tend to large or small asymptotic value at high-energy limit.

The inflationary parameters have been investigated up to the leading log level with respect to the scalar quartic coupling in Ref. [2]. The quantum corrections introduce the quartic coupling dependence for n_s and r, but do not alter the attractor behavior. The standard model (SM) Higgs inflation has been investigated up to the next to leading log level in Refs. [10,11]. In SM the scalar quartic coupling is extremely suppressed near the Planck scale. It has been pointed out that a large non-minimal scalar curvature coupling is necessary to reproduce the observed Higgs mass, n_s and r. The remark is in order. Quantum field theory in curved spacetime induces log terms in the scalar four-point as well as in

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